

# AKTASTINIAN (EARLY ARTINSKIAN, EARLY PERMIAN) BRACHIOPODS FROM THE JIMBA JIMBA CALCARENITE, WOORAMEL GROUP, CARNARVON BASIN, WESTERN AUSTRALIA

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The brachiopod fauna of the Jimba Jimba Calcarenite, Carnarvon Basin, Western Australia is reviewed and described. New species named are *Neochonetes (Sommeriella) cockbaini*, *Cleiothyridina ovalis* and *Crassispirifer condoni*. The fauna is assigned to the *Strophalosia jimbaensis* Zone and an Aktastinian (Early Permian) age is preferred for the fauna.

THE CARNARVON Basin contains the best preserved Early Permian marine succession of all the Western Australian intracratonic basins and one of the richest sequences of Permian Gondwanan marine faunas. Brachiopod faunas from the Wooramel Group have received relatively minor attention until recently, apart from a few species from the Jimba Jimba Calcarenite described by Waterhouse (1970), Archbold (1983, 1986) and Archbold & Thomas (1986a), and small faunas from the Onc Gum and Billidee formations recently documented by Archbold (1991). The present study describes the moderately diverse brachiopod fauna of the Jimba Jimba Calcarenite which is stratigraphically below the Billidee Formation. This fauna has been referred to in several reports (Condon 1967, Thomas 1969, Playford et al. 1975) although only a few specimens have been described and figured. Documentation of the fauna confirms its biostratigraphical importance as well as its faunal relationship with, and distinction from, the fauna of the Callytharra Formation, which is stratigraphically below the Wooramel Group.

## STRATIGRAPHY

The stratigraphy and structure of the Carnarvon Basin have been reviewed by Playford et al. (1975) and by Hocking et al. (1987). Only the pertinent stratigraphy concerning the Jimba Jimba Calcarenite is summarised below.

The Jimba Jimba Calcarenite was originally proposed by Condon (1965: 7) as a 'formation of fossiliferous calcarenite with calcilutite and sandstone conformably between the Moogooloo Sandstone below and the Billidee Formation

above'. This calcarenite was also treated as a formation unit by Playford et al. (1975), but van de Graaff et al. (1977) and Hocking et al. (1987) considered the Jimba Jimba Calcarenite to be a member at the base of the Billidee Formation. We retain the unit as a formation because, although limited in outcrop, it is clearly mappable as shown by Condon (1967).

At its type section 15 km west of the Jimba Jimba Homestead the Jimba Jimba Calcarenite is 61 m thick. The unit is also recognised 14 km east of the type section (Condon 1967).

## PREVIOUS FAUNAL STUDIES

No fossils were listed from the Jimba Jimba Calcarenite by Condon (1965) who considered its age to be Artinskian 'by reference to its position above the Callytharra Formation'. Later, Condon (1967: 88-91) provided a short list of fossil names and noted that the Jimba Jimba fauna was 'superficially very like that of the Callytharra Formation'. His list included Bryozoa, crinoid ossicles, *Linoproductus* spp., *Neospirifer* spp., *Cleiothyridina*, *Phricodothyris*, *Dictyoclostus*, '*Chonetes*' and *Derbyia*. Additional fossil collections from the Jimba Jimba Calcarenite were made by Dr A. E. Cockbain and Mr B. S. Ingram in 1966 from the Kennedy Range Dam site. Cockbain (1966) compared the fauna and lithology of the Jimba Jimba Calcarenite with those of the underlying Callytharra Formation and concluded that the gross faunal and lithological aspects of the two units were nearly identical. In the same report, Cockbain listed for both the Jimba Jimba Calcarenite and the Callytharra Formation the following taxa: *Neochonetes*

*pratti* (Davidson), *Dictyoclostus callytharrensensis* (Prendergast), *Linoproductus cora foordi* (Etheridge) and *Neospirifer* spp. Waterhouse (1970) described and figured *Stepanoviella flexuosa* from the Jimba Jimba Calcarenite and also favoured an Aktastinian age for the unit.

Dickins (1963) drew attention to the moluscan faunas of the Wooramel Group, proposed a faunal Stage C for the bulk of the unit, and pointed out the close relationship of the assemblage with that of his Stage B (representing faunas from the Callytharra Formation and equivalent units). He indicated an Early Artinskian (Aktastinian) for Stage C. Runnegar (1969) and Waterhouse (1970) questioned the validity of Dickins's Stage C and suggested that it should be combined with Stage B. As a result, Cockbain (1980) considered the combined Stage B and C to be one biostratigraphical unit of 'a fairly long time range occurring at a number of shelly horizons, often of limited extent', and considered that it could not be used for detailed biostratigraphical correlation.

#### AGE OF THE JIMBA JIMBA CALCARENITE FAUNAL ASSEMBLAGE

The Aktastinian age usually ascribed to the Jimba Jimba Calcarenite was principally based on the stratigraphical position of the unit (overlying the Callytharra Formation and underlying the Billidee Formation) and the close relationship of the fauna with that of the Callytharra Formation. Ammonoids from the Callytharra Formation and the top of the Billidee Formation are regarded as indicating late Sakmarian (Sterlitamakian) and late Artinskian (Baigendzhinian) ages respectively (Glenister & Furnish 1961, Hocking et al. 1987). Alternative suggestions that the Wooramel Group may be Baigendzhinian in age (Cockbain 1980) have been discussed by Archbold (1991).

Dickins (1963) and Archbold (1991) concluded that, although the Wooramel Group and the Callytharra Formation have some species in common, the two faunas have distinctive elements. Further data to support this view are presented in the present study. Several brachiopod species from the Jimba Jimba Calcarenite occur in the Callytharra Formation, including *Callytharella callytharrensensis* (Prendergast), *Neospirifer* cf. *N. hardmani* (Foord), *Trigonotreia neoaustralis* Archbold & Thomas and *Cleiothyridina* cf. *C. baracoodensis* (Etheridge). Species occurring abundantly in, and confined

to, the Wooramel Group include *Strophalosia jimbaensis* Archbold (known from the Jimba Jimba Calcarenite and from both the One Gum and Billidee formations), *Neochonetes* (*Sommeriella*) *cockbaini* sp. nov., *Cleiothyridina ovalis* sp. nov. and *Globiella flexuosa* Waterhouse (all restricted to the Jimba Jimba Calcarenite). Characteristic species from the Callytharra Formation such as *Permorthotetes callytharrensensis* Thomas, *Tornquistia occidentalis* Archbold, *Stictozoster senticosa* (Hosking), *Strophalosia irwinensis* Colman, *Heteralosia etheridgei* (Prendergast), *Elivina hoskingae* Archbold & Thomas, *Tomiopsis woodwardi* Archbold & Thomas and *Spirelytha fredericki* Archbold & Thomas have not been discovered in the Wooramel Group. There are also differences between the Callytharra Formation and the Wooramel Group in the bivalve and gastropod faunas (Dickins 1963: 10, also figs 3–5). Foraminifera from the Jimba Jimba Calcarenite are distinctive and represent a younger zone than those of the Callytharra Formation (Palmieri 1990).

In summary, in view of the distinctive and abundant species confined to the Wooramel Group and the many characteristic forms of the Callytharra Formation which are absent from the Wooramel Group, we consider that the fauna from the Wooramel Group represents an important and separable biostratigraphical horizon. An Aktastinian age was argued for the Wooramel Group by Archbold (1991).

#### PRESERVATION, DEPOSITORIES AND LOCALITIES

Material from the Jimba Jimba Calcarenite is moderately well preserved, generally as calcareous shells, but many specimens are incomplete and frequently decorticated because of the difficulty of extracting specimens from a limestone. Specimens occur in a relatively homogeneous, in some cases friable, grey to yellow fossiliferous calcarenite with minor calcilutite consisting predominantly of brachiopod, bryozoan and crinoid fragments.

The described material is housed in the Geological Survey of Western Australia, Perth (GSWA) and the Australian Geological Survey Organisation, Canberra (AGSO). GSWA material was collected by Dr A. E. Cockbain and Mr B. S. Ingram from a reference section of the Jimba Jimba Calcarenite at the Kennedy Range Dam site (GSWA field numbers F6243–F6248).

F6251–F6254) and by Dr S. K. Skwarko from the type section of the Jimba Jimba Calcarenite (GSA field number 94218). The Kennedy Range Dam site is across the Gascoyne River, just north of the Jimba Jimba type locality. AGSO material was also collected from the type section of the Jimba Jimba Calcarenite (AGSO locality WO3) and is registered in the Commonwealth Palaeontological Collection (numbers with CPC prefix).

### SYSTEMATIC PALAEOLOGY

The brachiopod fauna of the Jimba Jimba Calcarenite consists of the following species. All species are illustrated but only new species and material adding to the description of previously named species are described in this study.

*Permorthotetes* cf. *P. lindneri* Thomas, 1958 (Fig. 8A)

*Neochonetes* (*Sommeriella*) *cockbaini* Archbold sp. nov. (Fig. 1A–L)

*Strophalosia jimbaensis* Archbold, 1986 (Fig. 2A–J)

*Reedoconcha?* sp. (Fig. 3A)

*Callytharrella callytharrensensis* (Prendergast, 1943) (Fig. 3N, O)

*Costatumulus* cf. *C. irwinensis* (Archbold, 1983) (Fig. 3C–G, L)

*Globiella flexuosa* (Waterhouse, 1970) (Fig. 3B, H–K)

Productidina or Chonetidina indet. (Fig. 3M)

*Cleiothyridina ovalis* Shi sp. nov. (Fig. 4A–P)

*Cleiothyridina* cf. *C. baracoodensis* (Etheridge, 1903) (Fig. 5A–G)

*Cyrtella?* sp. (Fig. 6A, B)

*Neospirifer hardmani* (Foord, 1890) (Fig. 6C–E, J)

*Neospirifer* cf. *N. foordi* Archbold & Thomas, 1986a (Fig. 6F–I, K)

*Crassispirifer condoni* Archbold & Shi sp. nov. (Fig. 7A–N)

*Trigonotreta neoaustralis* Archbold & Thomas, 1986a (Fig. 8B–E)

*Tomtops* cf. *T. rarus* Archbold & Thomas, 1986b (Fig. 8G–I)

*Spirelytha* sp. (Fig. 8F)

*Hoskingia?* sp. (Fig. 8J)

Subfamily RUGOSOCHONETINAE Muir-Wood, 1962

Genus *Neochonetes* Muir-Wood, 1962

Subgenus *Neochonetes* (*Sommeriella*) Archbold, 1982

*Type species.* *Chonetes prattii* Davidson, 1859.

*Neochonetes* (*Sommeriella*) *cockbaini* Archbold sp. nov.

Fig. 1A–L

*Neochonetes* (*Sommeria*) *prattii*.—Archbold 1981: 114, fig. 5V, W (*non cet.*).

*Etymology.* For Dr A. E. Cockbain, geologist and palaeontologist.

*Holotype.* CPC 19869, a complete shell, from the type section of the Jimba Jimba Calcarenite (AGSO locality WO3).

*Paratypes.* GSWA F43871–F43872, two juvenile dorsal valves, from GSWA locality F6244; GSWA F43873, one mature dorsal valve, from GSWA locality F6252; CPC 31484–31488, CPC 19869, one incomplete dorsal valve, four complete shells and one incomplete shell, all from AGSO locality WO3.

*Size ranges.* Maximum width: 14–40 mm; hinge width: 14–36 mm; shell height: 8–24 mm; shell thickness: 5–9 mm.

*Diagnosis.* Very large *Neochonetes* (*Sommeriella*) with deep, relatively narrow sulcus and robust dorsal septa at maturity.

*Description.* Convexity of ventral valve distinct with prominent sulcus arising close to umbo, usually with deep median valley. Dorsal valve planar to gently concave with narrow, distinct fold developed anterior to umbo, broadening to anterior valve margin. Greatest width of shell at midlength or anterior to midlength. Exterior surface with weakly developed growth lines and fine capillae (about 3–4 per mm at 1 cm from umbo), increasing in number by bifurcation. Ventral interarea low, dorsal interarea very low. Cardinal spines poorly known. Ventral umbo low, rounded.

Ventral interior poorly known. Teeth short, stout. Delthyrium broad, relatively small.

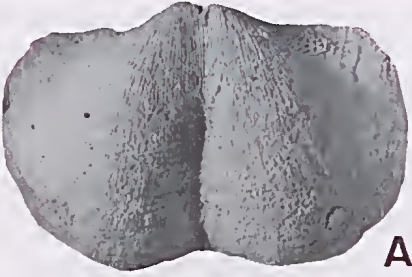
Cardinal process low, robust at maturity. Chilidium not known. Alveolus deep, prominent at base of process at maturity. Socket ridges prominent, sockets distinct, deep, lateral septa and median septum prominent and thickened at maturity, weakly developed in submature individuals. Brachial ridges indistinct. Interior of submature valves with rows of radial papillae.

Order CHONETIDA Nalivkin, 1979

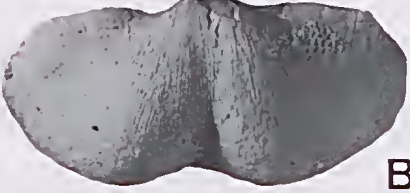
Suborder CHONETIDINA Muir-Wood, 1955

Superfamily CHONETACEA Bronn, 1862

Family RUGOSOCHONETIDAE Muir-Wood, 1962



A



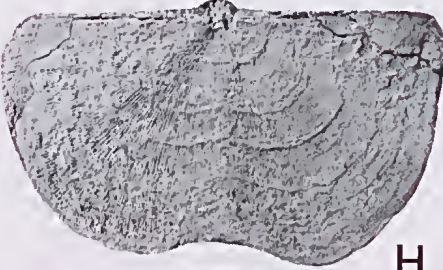
B



C



D



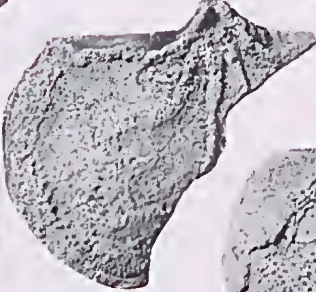
H



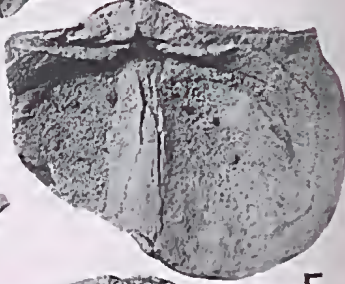
K



E



G



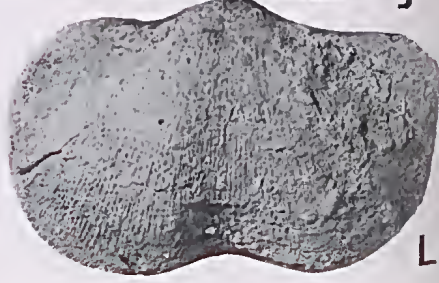
F



I



J



L

Fig. 1. *Neochonetes (Sommeriella) cockbaini* Archbold sp. nov. A–D, CPC 19869, holotype, complete shell in ventral, posteroventral, anterior and dorsal views,  $\times 1.8$ . E, GSWA F43871–F43872, juvenile dorsal valves, interior views,  $\times 3.5$ . F, CPC 31485, incomplete shell in dorsal view,  $\times 1.8$ . G, CPC 31484, incomplete dorsal valve, interior view,  $\times 2$ . H, GSWA F43873, dorsal valve exterior view,  $\times 1.5$ . I–J, CPC 31486, shell in ventral and dorsal views,  $\times 1.8$ . K, CPC 31487, shell in ventral view,  $\times 2$ . L, CPC 31488, shell in ventral view,  $\times 2.5$ .

At full maturity papillac restricted to anterior and lateral margins of valve interior. Posterior margin of valve smooth.

**Discussion.** This distinctive large species can be differentiated from *N. (S.) prattii* (Davidson) (see Archbold 1981 for description of species) by its large size, characteristic deep sulcus and robust dorsal septa at maturity. *N. (S.) prattii* from the Sterlitamakian Callytharra Formation and correlative units in Western Australia is probably ancestral to *N. (S.) cockbaini*.

The younger species *N. (S.) tenuicapillatus* Archbold, 1981 from the Late Baigendzhinian Wandagee Formation possesses a more deeply concave dorsal valve and finer capillae than the new species.

Order PRODUCTIDA Sarycheva & Sokolskaya, 1959

Suborder STROPHALOSIIDINA Waterhouse, 1975

Superfamily STROPHALOSIACEA Schuchert, 1913

Family STROPHALOSIIDAE Schuchert, 1913

Subfamily STROPHALOSIINAE Schuchert, 1913

Genus *Strophalosia* King, 1844

*Type species. Strophalosia gerardi* King, 1846.

*Strophalosia jimbaensis* Archbold, 1986

Fig. 2A–J

*Strophalosia jimbaensis* Archbold 1986: 102, fig. 2A–G.—Archbold 1991: 60, fig. 3A–P (with synonymy).

**Holotype.** CPC 24405, a conjoined shell from the type section of Jimba Jimba Calcarenite, Carnarvon Basin, figured by Archbold (1986).

**Size ranges.** Maximum width: 26–43 mm; hinge width: 12–25 mm; shell height: 25–39 mm; shell thickness: 25–18 mm; ventral interarea height: 1.5–4 mm; dorsal interarea height: 1–2 mm.

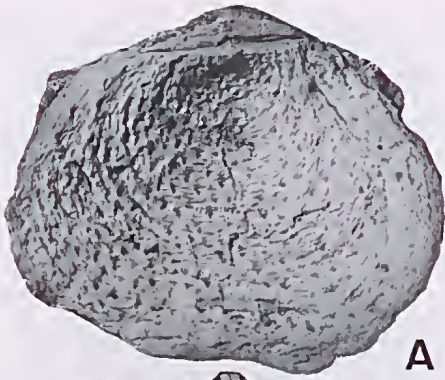
**Description.** Juvenile or submature shells slightly elongately oval in outline, mature specimens transversely oval; maximum width at midlength.

Hinge width varies from about 0.43 of maximum width to 0.70 of maximum width. Ventral interarea broadly triangular in shape in most

specimens, rarely high and narrowly triangular, flat or very gently concave, finely striated parallel to hinge line. Delthyrium relatively small and narrow, filled with small, gently convex pseudo-deltidium. Umbo small and broad, little extended, with broad umbonal angle varying from  $93^\circ$  to  $130^\circ$ , truncated by usually weakly developed cicatrix which is relatively small (4 mm in diameter in largest specimens). Ears very small, ill-defined. Cardinal extremities broadly rounded. Umbonal slopes gently convex. Lateral and anterior slopes high and steep. Gentle median sulcus is present in most ventral specimens examined, commences from about posterior third of shell curvature length and persists until anterior margin of shell, always shallow and broad, strongest over midlength of valve. Dorsal valve moderately and evenly concave. Dorsal interarea distinct, broad, usually slightly lower than ventral interarea, bisected by small, triangular notothyrium filled by gently convex chilidium.

Ventral valve ornament consists of spines and broad, weakly developed concentric lamellae. Coarse, suberect spines appear in a row along hinge line and in up to three rows on cars, 0.8 mm across spine base. Body spines numerous and evenly scattered on venter, slightly smaller than spines on cars, suberect, with swollen bases about 0.6–1 mm across, quincuncially arranged, 2–2.5 mm apart. Concentric lamellae ill-defined in most specimens; fine growth lamellae at times crowded together to form broad steps 2–5 mm wide. Dorsal valve lacks spines but possesses strongly developed concentric lamellae, 5–8 in 5 mm, and quincuncially arranged subcircular to elongate dimples which are 0.8–1 mm in diameter and numbering 3–4 in 5 mm.

Cardinal process arises from strong median septum and lateral ridges which surround small, deep sockets. Cardinal process moderately high, erect, inclined at up to  $65^\circ$  to plane of dorsal visceral disc, trilobed in external view with central lobe being most prominent, quadrilobed in internal view because of development of fine median depression on central lobe. Median septum extends to about midlength of dorsal valve, with tapering anterior end. Adductors



A



B



C



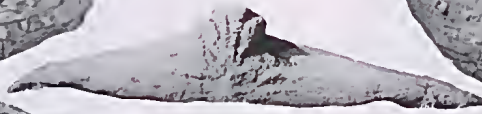
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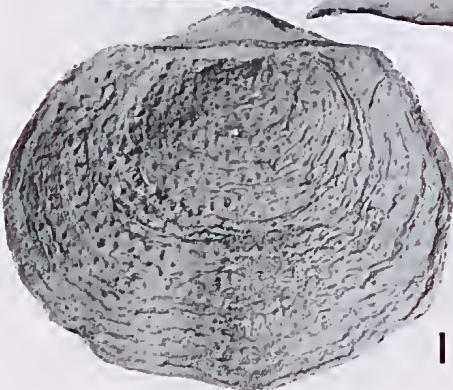
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G



H



I



J

Fig. 2. *Strophalosia jimbaensis* Archbold, from GSWA locality F94218. A, F, GSWA F43874, shell in dorsal and ventral views,  $\times 1.6$ . B, GSWA F43875, shell in ventral view,  $\times 1.6$ . C, G, GSWA F43876, dorsal valve interior view and cardinal process external view,  $\times 1.6$  and  $\times 3$ . D, H, GSWA F43877, shell in lateral and anteroventral views,  $\times 1.6$ . E, GSWA F43878, dorsal valve interior view,  $\times 1.6$ . I, GSWA F43879, gerontic shell in dorsal view,  $\times 1.3$ . J, GSWA F43880, shell in ventral view,  $\times 1.6$ .

elongately oval in shape, smooth, bisected by median septum, moderately differentiated with anterior adductors being most prominent. Brachial ridges narrow, slightly to moderately elevated above disc floor, smooth. A distinct marginal ridge present in one dorsal interior, surrounding visceral disc. Numerous fine papillae present on floor of visceral disc with exception of brachial ridges and adductors, as well as on anterior trail where papillae may be arranged in distinct rows. Slight anterior thickening of dorsal valve occurs in all specimens available but varies in degree of development.

**Discussion.** The species was defined by Archbold (1986) on the basis of only four poorly preserved specimens, no isolated dorsal valves being available. The present study of topotypic material has confirmed characteristics of the species such as the large size at maturity, the weak ventral sulcus, and the strongly developed concentric lamellae and dimples on the dorsal valve.

The species was compared with allied forms by Archbold (1986: 102; 1991: 62).

#### Order ATHYRIDIDA Dagys, 1974

#### Superfamily ATHYRIDACEA McCoy, 1844

#### Family ATHYRIDIDAE McCoy, 1844

#### Genus *Cleiothyridina* Buckman, 1906

*Type species.* *Atrypa pectinifera* Sowerby, 1840.

#### *Cleiothyridina ovalis* Shi sp. nov.

Fig. 4A–P

**Etymology.** In reference to the oval outline of the species.

**Holotype.** GSWA F43896, a complete submature shell from GSWA locality F94218, Jimba Jimba Calcarenite, Carnarvon Basin.

**Paratypes.** GSWA F43894, one ventral valve, from GSWA locality F6252; GSWA F43895, a complete shell, from GSWA locality F6243; GSWA F43896–F43903, one complete shell and seven ventral valves, from GSWA locality 94218.

**Size ranges.** Maximum width: 21–46 mm; shell length: 21–32 mm; shell thickness: 8.2 mm (measured from holotype, the only one that appears not to have been crushed or distorted); ratio of shell length to width: 1

(immature)–0.84 (mature); width of ventral muscle field: 0.7–0.9 mm; length of ventral muscle field: 11–15 mm.

**Diagnosis.** Shells of small to medium size for genus; slightly transversely oval at maturity, gently plano-convex to gently concavo-convex in lateral profile; anterior commissure uniplicate; concentric growth lamellae pronounced, numbering 8–14 in 5 mm at midlength of mature specimens.

**Description.** Most specimens crushed and compressed to varying degrees but all appear to be gently plano-convex to gently concavo-convex in lateral profile. Outline slightly elongately oval in immature specimens, transversely oval at full maturity. Maximum width at midlength.

Ventral valve flat or gently concave in overall appearance although umbonal region usually gently swollen. Ventral umbo erect, moderately extended, truncated by small foramen of 1–2 mm diameter. Immature specimens almost lack sulcus, with nearly rectimarginate anterior commissure. Mature specimens with very gentle median depression which deepens particularly at anterior margin, giving rise to moderately strongly uniplicate anterior commissure. Dorsal valve gently to moderately convex, fastigium weakly developed, median fold results in uniplicate anterior commissure.

Concentric growth lamellae pronounced on both valves, numbering 8 in 5 mm at 8 mm from ventral umbo, 10 in 5 mm at midlength of shell, and 15 or more in 5 mm near anterior margin where a geniculate band 5–7 mm wide with crowded growth lamellae is observed in all large (mature) specimens. Presence of this geniculate band probably indicates full maturity of shells. Shell surfaces too abraded to preserve radial spines in most specimens, but traces of radial lines on lamellae present on some specimens.

Teeth robust, rounded, supported by dental plates which are fused into umbonal wall. Ventral muscle field relatively large, occupying third to almost half ventral valve floor, well differentiated into adductor and diductor scars. Adductor scars heart-shaped, located at posterior end of muscle field just below teeth, well depressed,

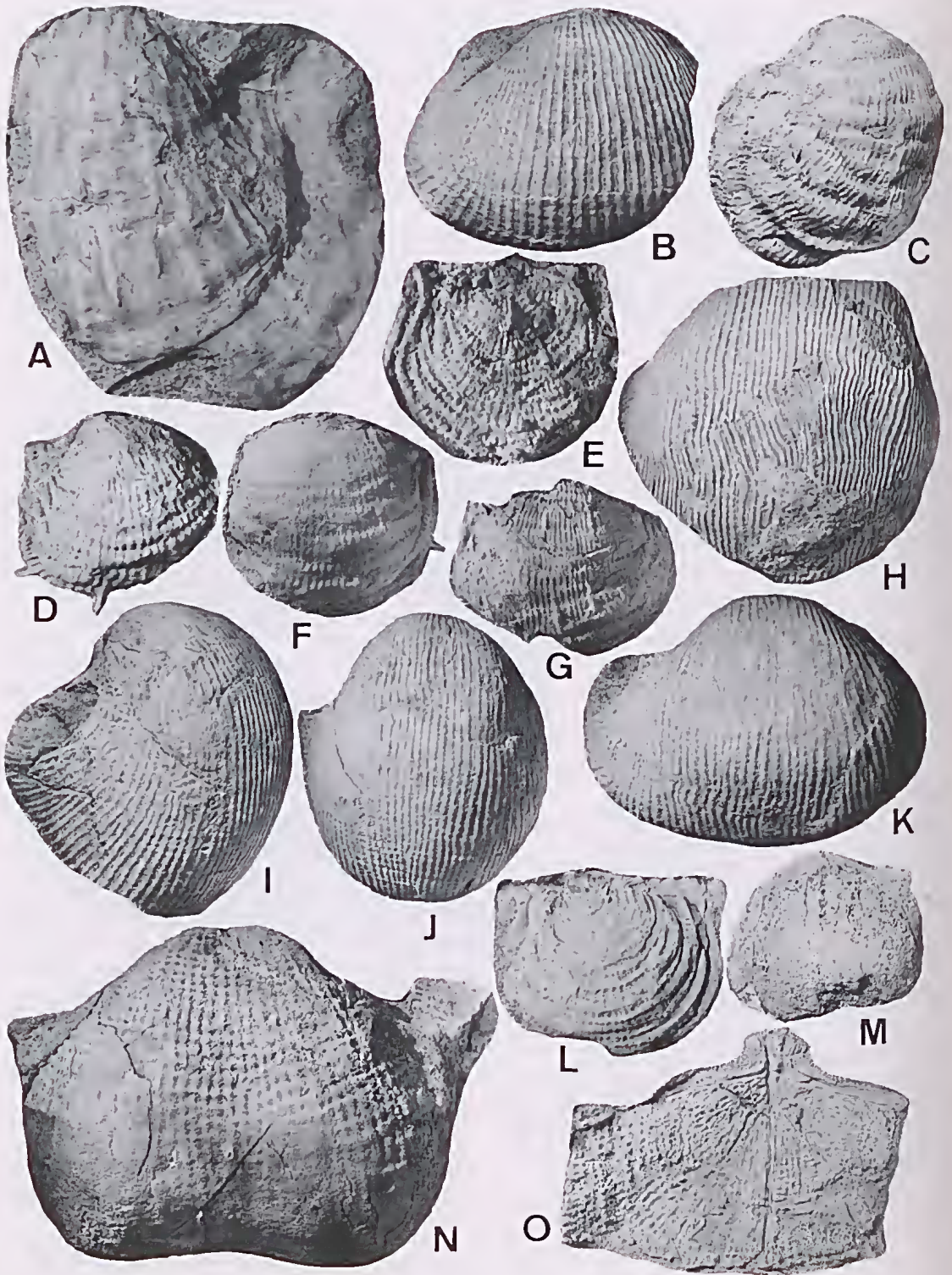




Fig. 3. A, *Reedoconcha?* sp., GSWA F43881, from locality F6248, incomplete ventral valve in ventral view,  $\times 2.2$ . B, H-K, *Globiella flexuosa* (Waterhouse). B, GSWA F43882, from locality F6247, ventral valve in ventral view,  $\times 1.5$ . H, GSWA 43883, from locality F6247, ventral valve in anteroventral view,  $\times 1.5$ . I, J, GSWA F43884, from locality F6247, ventral valve in lateral and ventral views,  $\times 1.5$ . K, GSWA 43885, from locality F6244, ventral valve in ventral view,  $\times 1.5$ . C-G, L, *Costatumulus* cf. *C. irwinensis* (Archbold). C, GSWA F43886, from locality F6248, ventral valve in lateral view,  $\times 1.8$ . D, GSWA F43888, from locality F6247, ventral valve in ventral view,  $\times 2$ . E, GSWA F43891, from locality F6244, dorsal valve interior view,  $\times 2$ . F, GSWA F43889, from locality F6247, ventral valve in ventral view,  $\times 1.6$ . G, GSWA F43887, from locality F6248, ventral valve in ventral view,  $\times 1.6$ . L, GSWA F43890, from locality F6247, dorsal valve interior view,  $\times 2$ . N, O, *Callytharrella callytharrensensis* (Prendergast). N, GSWA F43892, from locality F6246, ventral valve in ventral view,  $\times 1.2$ . O, CPC 31489, decorticated dorsal valve in dorsal view,  $\times 1$ . M, Productidina or Chonetidina indet., GSWA F43893, from locality F6243, ventral valve in ventral view,  $\times 2$ .

smooth, anteriorly passing onto low but prominent median ridge bisecting diductors. Diductor scars large, deeply depressed, separated from rest of valve floor by raised ridges, weakly striated. Remainder of valve floor marked by radial, in places anastomosing, vascular markings. Interior of dorsal valve unknown.

**Discussion.** The material is characterised by the low convexity, the ill-defined sulcus and the absence of a fold, and by the distinct uniplicate anterior commissure at maturity. These characteristics are also displayed by the specimens from the Callytharra Formation figured by Foord (1890) and Etheridge (1903) as *Cleiothyris* (= *Cleiothyridina*) *macleayana* (not Etheridge 1889), judged from their illustrations and descriptions. The type material of *Cleiothyridina macleayana* (Etheridge 1889: 208, pl. 17, figs 1-5) from the Baigendzhinian Noonkanbah Formation of the Canning Basin resembles the new species in size, outline and the anterior commissure but is clearly distinguished by its much more convex dorsal valve. The same is true of the comparison with *C. semiconcava* Waagen (1884: 481, pl. 41, figs 4-6) from the Late Artinskian to Kungurian Amb Formation of the Salt Range, Pakistan. The Salt Range species is further distinguished by its more strongly folded anterior commissure. *C. roysii* var. *penta* Prendergast (1935: 24, pl. 2, figs 13-15) from the Luilugui Station, Kimberley Division, approaches the new species in size and particularly in its flat to gently concave ventral valve, but this species is pentagonal in outline and has a high dorsal valve and a deep, well pronounced sulcus and strongly uniplicate anterior commissure. *C. baracoodensis* (Etheridge 1903: 17, pl. 3, figs 5-9) from the Callytharra Formation of the Carnarvon Basin is distinguished from the new species by its gently to moderately convex ventral valve and more inflated dorsal valve.

*Cleiothyridina seriata* Grant (1976: 199, pl. 53, figs 1-30, pl. 54, figs 1-62, text-fig. 18) from the Baigendzhinian or Kungurian fauna of the Rat Buri Limestone in south Thailand is smaller in size, more rounded in outline, and moderately biconvex in profile in comparison with *C. ovalis*. Another species figured as *Cleiothyridina* sp. from the Sterlitamakian fauna of the Ka Yao Noi Formation of south Thailand (Waterhouse et al. 1981) is also small and little inflated like the Jimba Jimba material. The Thai form was said to be immature and thus cannot be identified or compared with any named species with certainty, but it differs from *C. ovalis* in being rounded in outline rather than elongately oval or transversely oval.

Order SPIRIFERIDA Waagen, 1883  
Superfamily SPIRIFERACEA Waagen, 1883  
Family SPIRIFERIDAE King, 1846  
Subfamily NEOSPIRIFERINAE Waterhouse,  
1968

Genus *Crassispirifer* Archbold & Thomas,  
1985

*Type species. Spirifer rosalinus* Hosking, 1931.

*Crassispirifer condoni* Archbold & Shi sp. nov.

Fig. 7A-N

**Etymology.** For Mr M. A. Condon, who first proposed and mapped the Jimba Jimba Calcarenite in the Carnarvon Basin.

**Holotype.** CPC 31493, a complete specimen with valves conjoined, from BMR locality WO3.

**Paratypes.** CPC 31493-31496, a complete shell, two dorsal valves and one ventral valve from BMR locality WO3. GSWA F43912-F43917, four ventral valves and two dorsal valves, all incomplete, from GSWA locality F6243.

**Size ranges.** Maximum width: usually 40-70 mm, rarely up to 90 mm; height: 18-32 mm; thickness

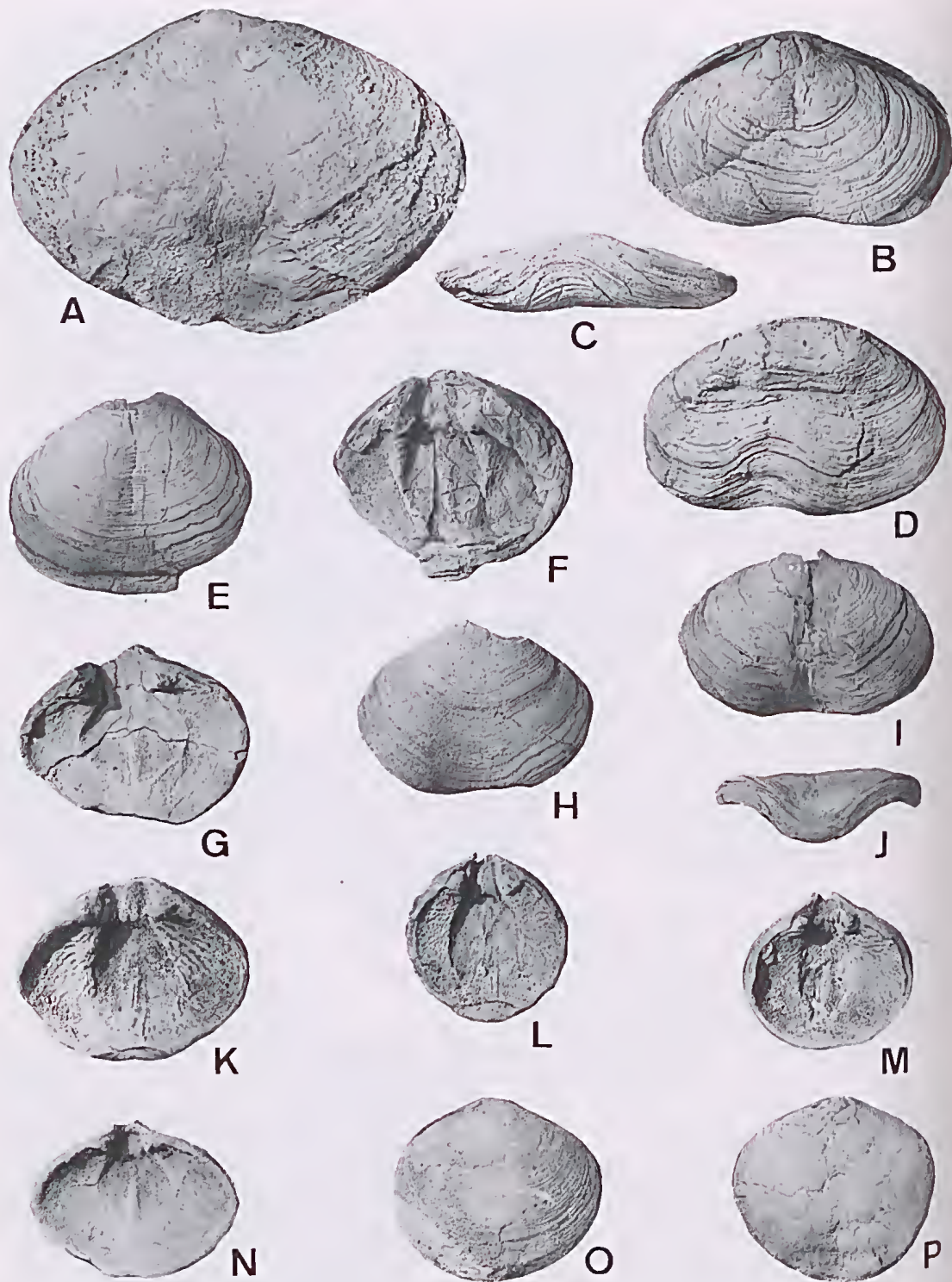




Fig. 5. *Cleiothyridina* cf. *C. baracoodensis* (Etheridge). A-D, GSWA F43904, from locality F6253, deccorticated shell in ventral, dorsal, anterior and lateral views,  $\times 1.22$ . E, GSWA F43906, from locality F6252, deccorticated ventral valve in ventral view,  $\times 1.2$ . F, GSWA F43907, from locality F6254, deccorticated ventral valve in ventral view,  $\times 1.2$ . G, GSWA F43905, from locality F6254, deccorticated ventral valve in ventral view,  $\times 2.5$ .

(measured from holotype only): 22 mm; width/height ratio: 2.5-2.9; dorsal valve height: 16-22 mm; ventral interarea height: 5-10 mm; dorsal interarea height: 2?-3 mm.

**Diagnosis.** Small, moderately convex *Crassispirifer* with broad and shallow sulcus and moderately high, well rounded fastigium. Lateral plicae weak to distinct. Costae equidimensional and low. Anterior sulcal tongue short.

**Description.** Shell transverse in outline with well extended cardinal extremities; widest at hinge margin.

Ventral valve moderately convex. Umbo small, moderately extended and incurved; umbonal slopes gently concave. Intercarea low and

wide, marked by both horizontal and vertical striations, divided by relatively large delthyrium; delthyrial plate unknown. Sulcus commences from umbo, initially defined by pair of prominent costae which at 8 to 10 mm from umbo become incorporated onto sulcal slopes; sulcus defined anteriorly by pair of plicae. Sulcus narrow and shallow over posterior third of ventral valve length, widens and deepens anteriorly towards anterior margin; sulcal floor broadly U-shaped in cross-section, terminates at front in short, rounded sulcal tongue. Lateral slopes gently convex, each bearing at least three low, indistinct plicae. Costae initially sharply defined, fine, equidimensional; anteriorly costae become relatively coarse and flattened,

Fig. 4. *Cleiothyridina ovalis* Shi sp. nov. A, GSWA F43894, ventral valve in ventral view,  $\times 2.5$ . B-D, GSWA F43896, holotype, crushed shell in ventral, anterior and dorsal views,  $\times 1.2$ . E, F, GSWA F43897, ventral valve in ventral and interior views,  $\times 1.2$ . G, H, GSWA F43898, ventral valve in interior and ventral views,  $\times 1.2$ . I, J, GSWA F43899, ventral valve in ventral and anterior views,  $\times 1.2$ . K, GSWA F43900, ventral valve interior view,  $\times 1.2$ . L, GSWA F43901, ventral valve interior view,  $\times 1.2$ . M, GSWA F43902, ventral valve interior view,  $\times 1.2$ . N, GSWA F43903, ventral valve interior view,  $\times 1.2$ . O, P, GSWA F43895, shell in dorsal and ventral views,  $\times 1.2$ .

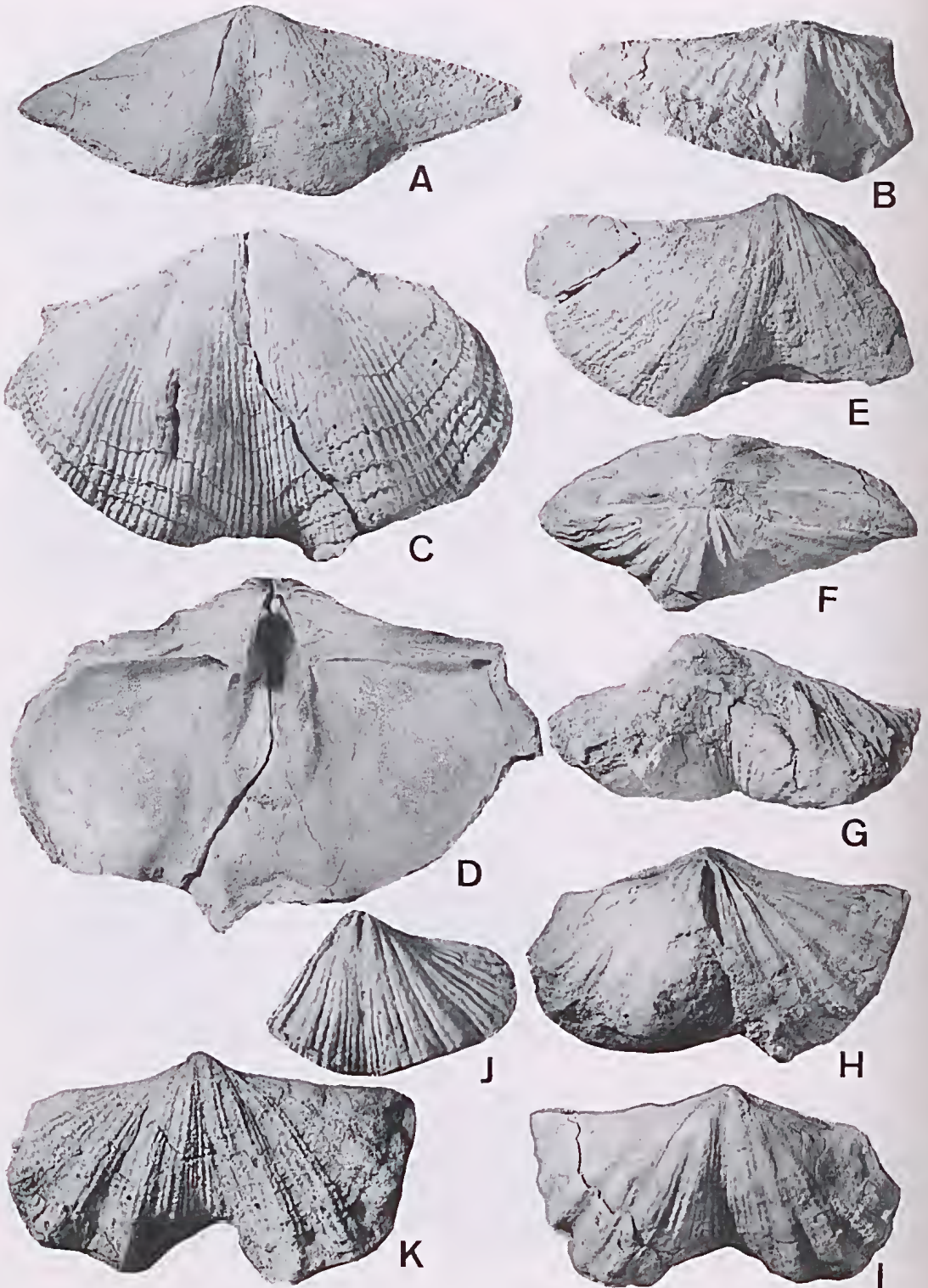


Fig. 6. A, B, *Cyrtella* sp. A, GSWA F43908, from locality F94218, ventral valve in ventral view,  $\times 1$ . B, GSWA F43909, from locality F6254, dorsal valve in dorsal view,  $\times 1.5$ . C-E, J, *Neospirifer hardmani* (Foord). C, D, CPC 31490, ventral valve in ventral view,  $\times 1$ . E, GSWA F43910, from locality F6255, ventral valve in ventral view,  $\times 1$ . J, GSWA F43911, from locality F6256, juvenile ventral valve in ventral view,  $\times 2$ . F-I, K, *Neospirifer* cf. *N. foordi* Archbold & Thomas. F-I, CPC 31491, shell in posterior, anterior, dorsal and ventral views,  $\times 1$ . K, CPC 31492, ventral valve in ventral view,  $\times 1$ .

between 0.8–1 mm wide. Median sulcal costa ill-defined, fine.

Dorsal valve of similar convexity to ventral valve; umbo small and low. Fastigium well differentiated from gently convex lateral slopes by low lateral depressions, generally low over posterior third of valve length, strongly elevated at front, giving rise to high, well rounded fold. Lateral plicae low and indistinct. Costae fine, equidimensional, numbering 5–6 in 5 mm at frontal margin.

Shell micro-ornament consists of prominent fine growth lamellae and poorly preserved capillae, with lamellae numbering 3–6 per mm and, on some specimens, crowded together to form broad growth steps, especially towards anterior margin.

Dental flanges stout, thickened, with prominent delthyrial ridges. Adminicula thickened and entirely buried in posterior shell thickening. Ventral muscle field longer than wide, deeply depressed below valve floor. Dorsal interior unknown.

*Discussion.* In outline, convexity, plication and sulcal details, the new species is similar to presumed juvenile specimens of *Fusispirifer carnarvonensis* Archbold & Thomas (1987: 177, figs 1E–F, 2D, F) from the Sterlitamakian Callytharra Formation but differs from those specimens in its higher fastigium, deeper sulcus and generally better defined lateral plicae. *Crassispirifer condoni* sp. nov. probably represents a small ancestral species of *Crassispirifer*, as indicated by its relatively robust shell and the development of extended anterior growth resulting in a trigonal shell outline. Other species assigned to *Crassispirifer* are larger and more subquadrate in outline and possess stronger lateral plications, broader sulci and higher fastigia (Archbold & Thomas 1985).

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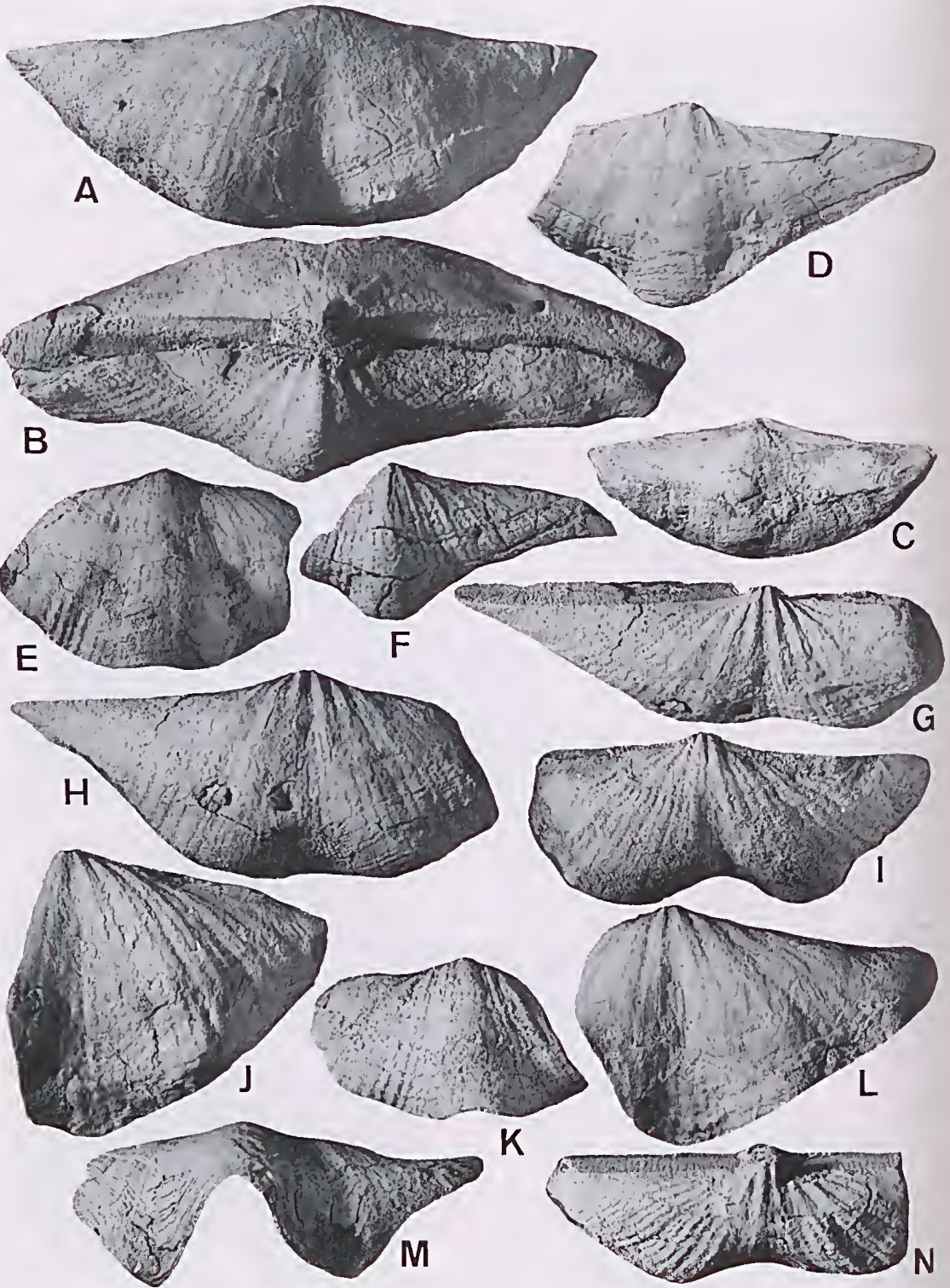


Fig. 7. *Crassispirifer condoni* Archbold & Shi sp. nov. A–C, CPC 31493, holotype, shell in ventral, posterior and dorsal views,  $\times 1.6$ ,  $\times 2$  and  $\times 1$ . D, M, CPC 31494, dorsal valve in dorsal and anterior views,  $\times 1.3$ . E, GSWA F43916, dorsal valve in dorsal view,  $\times 1.3$ . F, CPC 31495, dorsal valve in dorsal view,  $\times 1.3$ . G, H, CPC 31496, ventral valve in posterior and ventral views,  $\times 1.4$ . I, GSWA F43912, ventral valve in posteroventral view,  $\times 1.3$ . J, GSWA F43913, ventral valve in ventral view,  $\times 1.3$ . K, GSWA F43917, dorsal valve in dorsal view,  $\times 1.3$ . L, GSWA F43914, ventral valve in ventral view,  $\times 1.3$ . N, GSWA F43915, ventral valve in posterior view,  $\times 1.3$ .

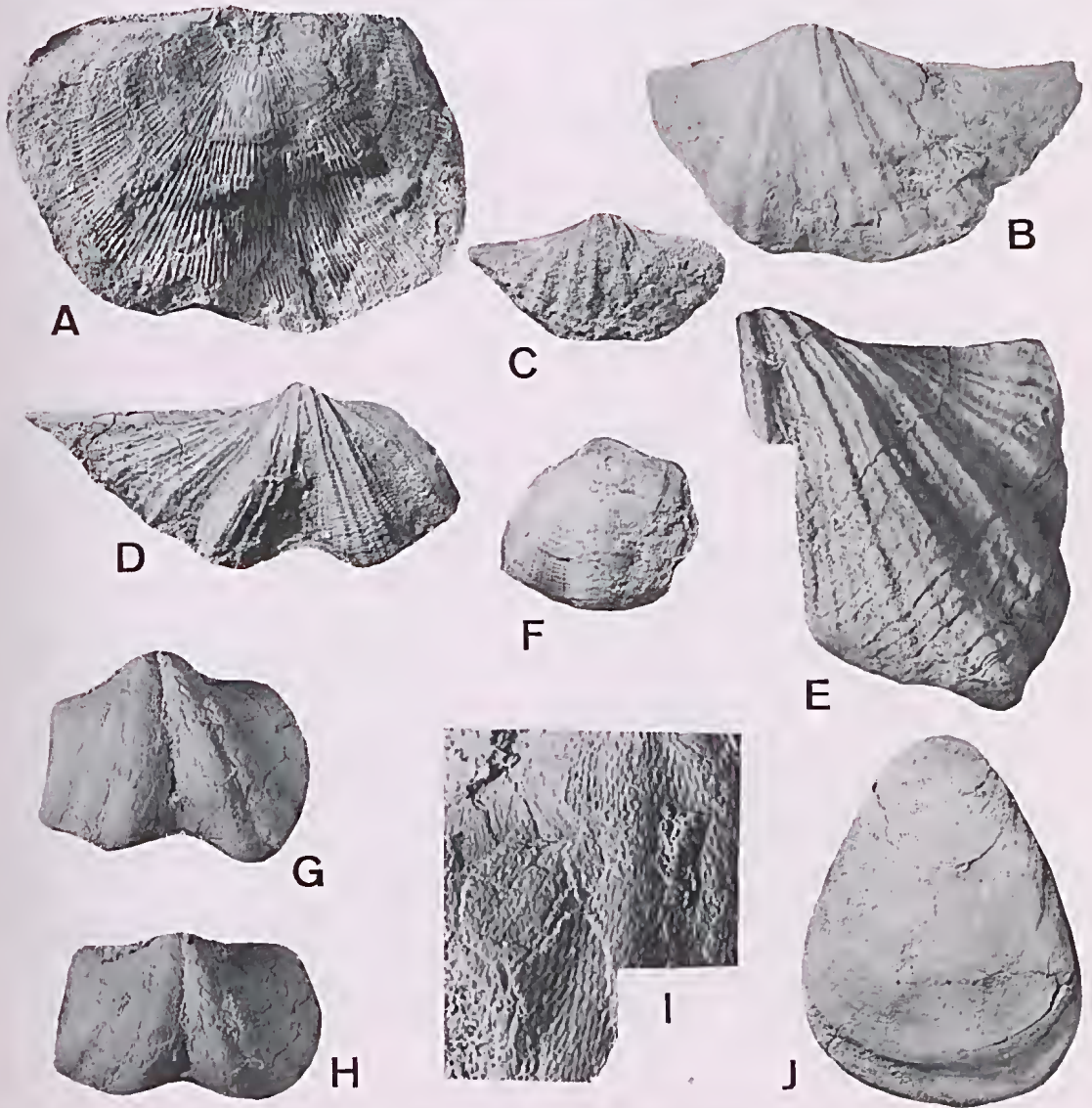


Fig. 8. A, *Permorthis* cf. *P. lindneri* Thomas, GSWA F43870, from locality F6248, ventral valve in ventral view,  $\times 1$ . B–E, *Trigonotreta neoaustralis* Archbold & Thomas. B, GSWA F49056, from locality F6253, ventral valve in ventral view,  $\times 1.3$ . C, CPC 31497, ventral valve in ventral view,  $\times 1$ . D, CPC 31498, ventral valve in ventral view,  $\times 1.5$ . E, GSWA F49057, from locality F6244, ventral valve in ventral view,  $\times 1$ . F, *Spirelytha* sp., GSWA F49058, from locality F6248, dorsal valve in dorsal view,  $\times 1$ . G–I, *Tomiopsis* cf. *T. rarus* Archbold & Thomas, GSWA F49059, from locality F6243, ventral valve in ventral and posterior views,  $\times 1.6$ , and micro-ornament enlarged,  $\times 8$ . J, *Hoskingia?* sp., CPC 31499, ventral valve in ventral view,  $\times 1.1$ .

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